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An evaluation of hard parts for age determination of pompano (*Trachinotus carolinus*), ladyfish (*Elops saurus*), crevalle jack (*Caranx hippos*), gulf flounder (*Paralichthys albigutta*), and southern flounder (*Paralichthys lethostigma*)

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ABSTRACT

An evaluation of marks on scales, otoliths, vertebrae, and dorsal and anal fin rays for age determination of pompano, ladyfish, crevalle jack, gulf flounder, and southern flounder was performed. Otoliths were selected as the most suitable age-determination structure. Otolith radii and marks had high positive correlations with fork lengths for pompano, ladyfish, and crevalle jack, and with total length for gulf flounder and southern flounder.

INTRODUCTION

This study was undertaken to determine which hard part was best for age determinations of pompano (*Trachinotus carolinus*), ladyfish (*Elops saurus*), crevalle jack (*Caranx hippos*), gulf flounder (*Paralichthys albigutta*), and southern flounder (*Paralichthys lethostigma*). The hard parts that were examined and compared were scales, otoliths, vertebrae, dorsal fin rays, and anal fin rays. In the northeastern Gulf of Mexico, these fishes have commercial value either as food or as bait for the snapper-grouper longline fishery. Biological information on these species for the Gulf of Mexico is sparse. Of these species, age determinations have been made for the two species of flounder by Nall (1979), who used whole otoliths. Comparisons of hard parts to determine the best structure for age determination for any of these species have not been made until now.

MATERIAL AND METHODS

Most of the fishes used in this study were obtained from northwest Florida during 1982. The exceptions were 24 crevalle jack that were collected in December 1982 from the Florida Keys. Specimens were dissected at the National Marine Fisheries Service Panama City Laboratory within 24 hours of receipt. They were iced and refrigerated if held overnight. Fork lengths (FL) and total lengths (TL) in millimeters (mm) were recorded for all fish. The hard parts (scales, otoliths, vertebrae, and dorsal and anal fin rays) were then removed, labeled, and stored.

Scales were removed from below the lateral line and posterior to the pectoral fin. They were stored in paper envelopes. Scales were cleaned in a solution of detergent and then mounted between two glass slides, and read on a dissecting microscope at 240X magnification. Scale impressions were also made by placing the wet scales between two plastic slides and impressed with a manual roller press.

Otoliths were removed, wiped clean, dried, and stored in 2-dram glass vials prior to preparation for reading. Otoliths, with the exception of those from pompano, were too thick to be read whole, so they were sectioned. Cross-sections (approximately 0.18 mm thick) were cut in 17 unit increments (1 unit = 0.0125 mm) with a low-speed saw. The sections were cut through, or as close as possible to, the focus. The sections were mounted on glass slides with Piccolyte cement and were viewed with a dissecting microscope at 240X magnification. Measurements were made from the focus to the distal margin along the axis of the cross-section (see Blacker 1974, p. 69, 71, and 72). Measurements in this text that have been made from the focus perpendicular to the sulcus acousticus to the distal margin (in cross-section) are henceforth referred to as the length-wise measurements ("A" in Fig. 1). Those made from the focus along the sulcus acousticus to the distal margin are henceforth referred to as width-wise measurements ("B" in Fig. 1). All measurements were made with an ocular micrometer where 1 unit = 0.0183 mm. An opaque band, using transmitted light, was considered a mark and was counted and measured to its distal edge. Whole otoliths from pompano were placed in a black dish containing glycerine, read, and measured under reflected light with a dissecting microscope at 240X magnification. The measurements consisted of the distances from the focus to the anterior edge of the otolith and from the focus to the distal edge of each mark.

For all species, except crevalle jack, the total vertebral column was examined and every other vertebrae cross-sectioned. The most representative vertebra (across all size ranges) was then selected and used for mark analysis. Because of the large size of the representative samples of crevalle jacks, only a portion of the vertebral column anterior to the caudal peduncle was sampled and cross-sectioned. The most representative vertebra was selected from that sample.

For all species except crevalle jack, the 9th and 10th vertebrae anterior to the hypural plate were removed and cleaned of excess flesh. For crevalle jack, the 6th vertebra was removed. After cleaning, all vertebrae were wrapped in cheesecloth and stored in cardboard boxes. The diameter of the anterior cone (Chadwick 1976) was measured for all species except crevalle jack. For the latter, the distance from the edge of the cone to the apex was measured in sagittal section (Berry et al. 1977). Measurements were made with a dissection microscope at 120X magnification where 1 ocular micrometer unit (omu) = 0.0183 mm. Because of the wide range in sizes of crevalle jack vertebrae, they had to be cross-sectioned and measured at 60X magnification where 0.75 omu = 1 mm. Crystal Violet and Alizarin Red S were used to stain the marks.

Dorsal and anal fin rays were removed, dried, and stored in paper envelopes prior to preparation for reading. Cross-sections of the rays were cut (0.30 mm thick) with a low-speed saw. The sections were mounted on glass slides with Piccolyte cement and were viewed with a dissecting microscope at 240X magnification.

Growth marks on scales, otoliths, and vertebrae were read using the criteria of Barger and Johnson (1982) and on dorsal and anal fin rays using the criteria of Chilton and Beamish (1982). The relationships between fish FL and (1) otolith radii, and (2) vertebral radii were determined by the least square method. On the assumption that marks were annular, back calculations of lengths at marks were computed.

RESULTS AND DISCUSSION

Of the hard parts, vertebrae and otoliths appeared to be the best structures for determining age for the investigated species. Dorsal and anal rays were rejected for all species, because marks were indistinguishable. Back calculated length at marks for vertebrae for all species are shown in Table 1 while back calculated length at marks for otoliths are in Table 2. Discussions for each species follow.

POMPANO

Of the pompano otoliths that were taken from 120 fish ranging in size from 76 mm FL to 358 mm FL, only one appeared to have a distinct mark. As a result, no regression analysis could be computed and no back calculations for FL could be made. Pompano scales were too small to be useful structures for age and growth studies. Only vertebrae were useful for age determination for pompano. For the 42 pompano vertebrae, marks were indicated from 0 to 2. The relation between FL and vertebral radii (VR) was FL = $6.1799 (VR)^{.8931}$, with a correlation coefficient (r) = .981.

LADYFISH

Ladyfish otoliths possessed distinct marks ranging from 0 to 6. Otoliths were sampled from 81 fish ranging in size from 238 mm FL to 604 mm FL. Widthwise measurements were made on each otolith. The resulting relation between FL and otolith radius (OR) was FL = $11.4124 (OR)^{.9319}$, with r = .856.

Ladyfish scales indicated possible marks ranging from 0 to 6. However, double banding was evident in approximately 50% of all examined scales. Larger fish showed variability in numbers of bands between scales taken from the same fish. Therefore, no analyses were done with scale data.

Eighty ladyfish vertebrae had marks ranging from 1 to 8, with double bands present in at least 30% of the vertebrae. The relation of VR to FL was FL = $8.4825 (VR)^{.9165}$, with r = .977.

CREVALLE JACK

Crevalle jack otoliths showed distinct growth marks. The 102 examined fish ranged in size from 84 mm FL to 934 mm FL. Otoliths taken from crevalle jack of less than 200 mm FL were read whole, whereas all others were cross-sectioned. Marks on the length-wise measurement ranged from 0 to 17. The relation of OR to FL was FL = $.2883 (OR)^{1.8346}$, with r = .928.

Crevalle jack scales were unsuitable, because the number of marks was not consistent on scales from the same fish. This result was obtained from fish throughout the size range.

Vertebrae from 100 crevalle jack were measured in cross-section with marks ranging from 0 to 7. Some double banding was present. The resulting relation between VR and FL was FL = $20.2538 (VR)^{.7648}$, with r = .991.

FLOUNDERS

Otoliths and vertebrae were useful age determination structures for both gulf and southern flounder. Scales, however, were unsatisfactory ageing structures for both species. Consistent markings on scales were lacking, and some marks were difficult to ascertain. Scale impressions did not clarify the problem.

Gulf flounder otoliths were taken from 139 fish ranging in size from 100 mm TL to 548 mm TL. All otoliths were cross sectioned and the lengthwise measurement was used for all calculations. The resulting relation between OR and FL was FL = -49.0377 + 6.2010 (OR), with r = .829.

In the 111 gulf flounder vertebrae that were examined, considerable double banding (see Landau, 1965, for a description of double banding in tuna) was present. For the purposes of this study, double bands were treated as a single mark and thus the marks ranged from 0 to 5. The resulting relation between VR and FL was $FL = 37.2579 + 4.3509\ (VR)$, with $r = .955$.

Otoliths from 123 southern flounder, ranging in size from 265 mm TL to 623 mm TL, were examined in cross-section. Marks from 0 to 4 were found. Length-wise measurements resulted in a higher correlation with FL than did width-wise measurements. The relation between OR to FL using the length-wise measurements was $FL = 3.1762\ (OR)^{1.1264}$, with $r = .807$.

Seventy-one southern flounder vertebrae were measured and marks ranged from 2 to 9. Double banding was present. The relation between VR and FL was $FL = 7.8186\ (VR)^{.8885}$, with $r = .930$.

CONCLUSIONS AND RECOMMENDATIONS

Dorsal and anal fin rays were unacceptable ageing structures, because satisfactory sections could not be made using the available equipment. Since other hard parts produced acceptable marks, efforts to improve techniques for examining dorsal and anal fin structures were not undertaken.

Fish scales were also unfavorable as an ageing structure for a variety of reasons. For pompano, scales were much too small for analysis and evaluation. For ladyfish, double bands were present in half of the samples. For crevalle jack, consistency of numbers of marks between scales from the same fish was absent. For larger fish of all species, regenerated scales became a problem. Smaller fish provided greater consistency, however, by 3-mark fish, variability began to occur. For these reasons, scales were not recommended as ageing structures for any of these species.

Vertebrae and otoliths were acceptable hard parts for ageing, because both meet the required criteria for use as an ageing structure. Marks were distinct in both structures for all species. Marks appeared to have a regular periodicity for both hard parts for all species. Both vertebrae and otoliths measurements were related to FL of the fish for all species. Double-banding did not occur in otoliths, whereas it was present in the vertebrae. Marks were less likely to be compressed and lost (as happens on vertebrae) on the otoliths. Otoliths were much easier to procure and handle without damage to the saleable product, whereas vertebrae required the dissection of the whole fish. Therefore, otoliths were chosen as the preferred ageing structure for all five species.

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Table 1. Mean back-calculated fork length (mm) at mark for 5 species of fish from the Gulf of Mexico using vertebrae.

Mark group	N	Mean empirical length	Mark 1	2	3	4	5	6	7	8
			Pompano							
1	30	276	202							
2	5	276	156	220						
Weighted mean			196	220						
N			35	5						
			Ladyfish							
1	18	269	217							
2	21	298	156	238						
3	7	441	233	286	340					
4	11	420	181	248	295	345				
5	10	447	173	253	296	339	373			
6	4	471	147	228	281	330	381	416		
7	4	526	152	213	278	311	367	410	442	
8	5	448	106	158	224	258	302	335	362	387
Weighted mean			178	239	293	325	358	383	398	387
N			80	62	41	34	23	13	9	5

Table 1. Continued

Mark group	N	Mean empirical length	Mark 1	2	3	4	5	6	7	8
			Crevalle jack							
1	23	276	191							
2	2	567	252	435						
3	6	686	243	383	550					
4	11	736	220	362	508	629				
5	11	771	211	343	480	598	690			
6	11	794	181	289	410	509	632	723		
7	1	784	132	191	263	458	541	596	687	
Weighted mean			204	340	474	575	655	712	687	
N			65	42	40	34	23	12	1	
			Gulf flounder							
1	46	259	165							
2	29	293	128	221						
3	17	351	124	206	289					
4	8	405	110	188	264	346				
5	9	391	94	150	215	279	333			
6	1	383	44	114	198	248	308	348		
Weighted mean			138	201	262	307	331	348		
N			110	64	35	18	10	1		

Table 1. Continued

Mark group	N	Mean empirical length	Mark 1	2	3	4	5	6	7	8	9
			Southern flounder								
1											
2	2	271	528	839							
3	10	349	128	211	278						
4	15	531	151	265	365	458					
5	13	406	77	172	231	292	343				
6	17	450	97	167	317	289	340	386			
7	9	504	64	146	201	259	315	373	438		
8	3	502	59	155	201	259	320	364	394	446	
9	1	434	68	107	186	212	260	294	336	364	405
Weighted mean			115	210	283	326	332	376	420	426	405
N			70	70	68	58	43	30	13	4	1

Table 2. Mean back-calculated fork length (mm) at mark for 4 species of fish from the Gulf of Mexico using otoliths.

Mark group	N	Mean empirical length	Mark 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ladyfish																			
1	13	297	256																
2	15	410	302	381															
3	17	438	309	375	413														
4	12	475	313	366	406	443													
5	2	519	309	380	432	468	500												
6	1	475	340	394	421	439	457	466											
Weighted mean			297	375	412	446	486	466											
N			60	47	32	15	3	1											
Crevalle jack																			
1	11	266	196																
2	6	283	144	219															
3	9	655	203	325	468														
4	15	716	184	296	443	598													
5	6	774	206	299	426	551	689												
6	3	792	187	263	371	451	584	727											
7	1	822	177	289	399	510	601	682	750										
8	1	845	224	331	507	617	696	737	758	801									
9	3	827	171	265	377	469	576	644	703	744	794								
10	0																		
11	2	839	167	260	351	412	516	556	598	674	736	773	802						
12	1	823	154	262	356	395	436	537	615	664	698	715	733	750					
13	0																		
14	0																		
15	0																		
16	0																		
17	1	850	180	259	291	325	349	439	537	629	645	710	744	761	778	796	814	831	850
Weighted mean			186	286	426	537	596	635	663	709	743	743	770	756	778	796	814	831	850
N			59	48	42	33	18	12	9	8	7	4	4	2	1	1	1	1	1

Table 2. Continued

Mark group	N	Mean empirical length	Mark 1	2	3	4	5
			Gulf flounder				
1	21	253	167				
2	89	324	149	237			
3	6	371	144	248	338		
4	1	320	195	238	271	292	
5	1	548	115	259	357	426	519
Weighted mean			152	238	332	359	519
N			118	97	8	2	1
			Southern flounder				
1	9	377	235				
2	75	409	166	363			
3	8	440	142	290	386		
4	1	580	144	233	351	460	
5	6	525	120	284	348	406	479
Weighted mean			167	350	368	414	479
N			99	90	15	7	6

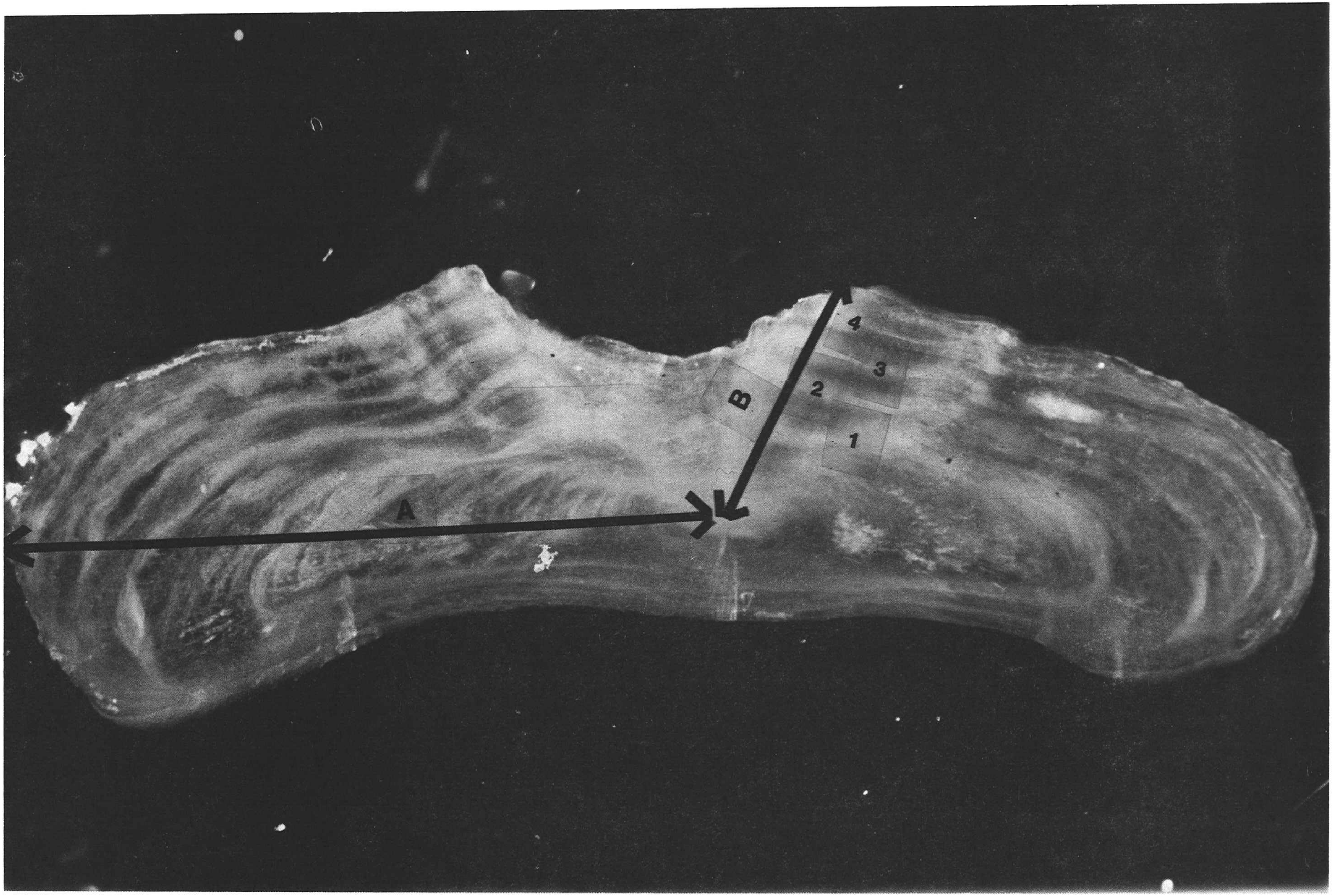

Figure 1. A cross-section of an otolith from a 623 mm TL female southern flounder showing the length-wise (A) measurement and the width-wise (B) measurement. Four + marks are indicated. (Photographed with reflected light.)